



International
Organization for
Standardization

Rotor Blade Maintenance

Presented by Gary Kanaby

20 July 2010

Safety - Professionalism - Experience - Craftsmanship - Value - Integrity



About Knight & Carver Wind Group®

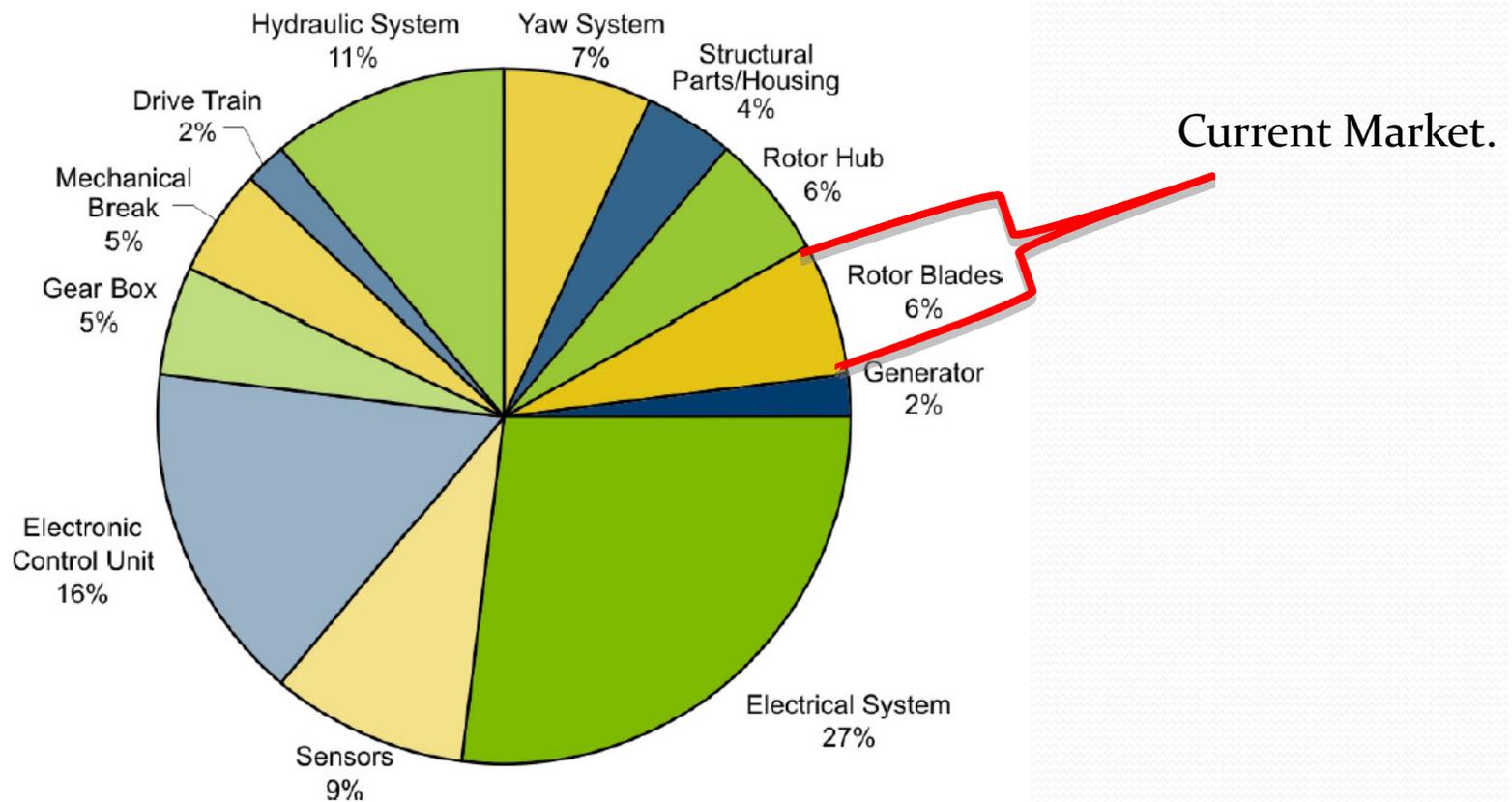
- Corporate Headquarter: National City, CA.
- Blade Factories in National City, CA and Howard, SD.
- Largest Blade Service Company in North America.
- ISO Registration & GL Shop Certification.
- Award Winning R&D Project with DOE/Sandia development of Sweep Twist Adaptive Rotor® (STAR®).
- License Agreement w/ Euros (Germany).
- Emphasis:
 - Safety.
 - Professionalism.
 - Experience.
 - Craftsmanship.
 - Value.
 - Integrity .



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Wind Turbine Services Overview

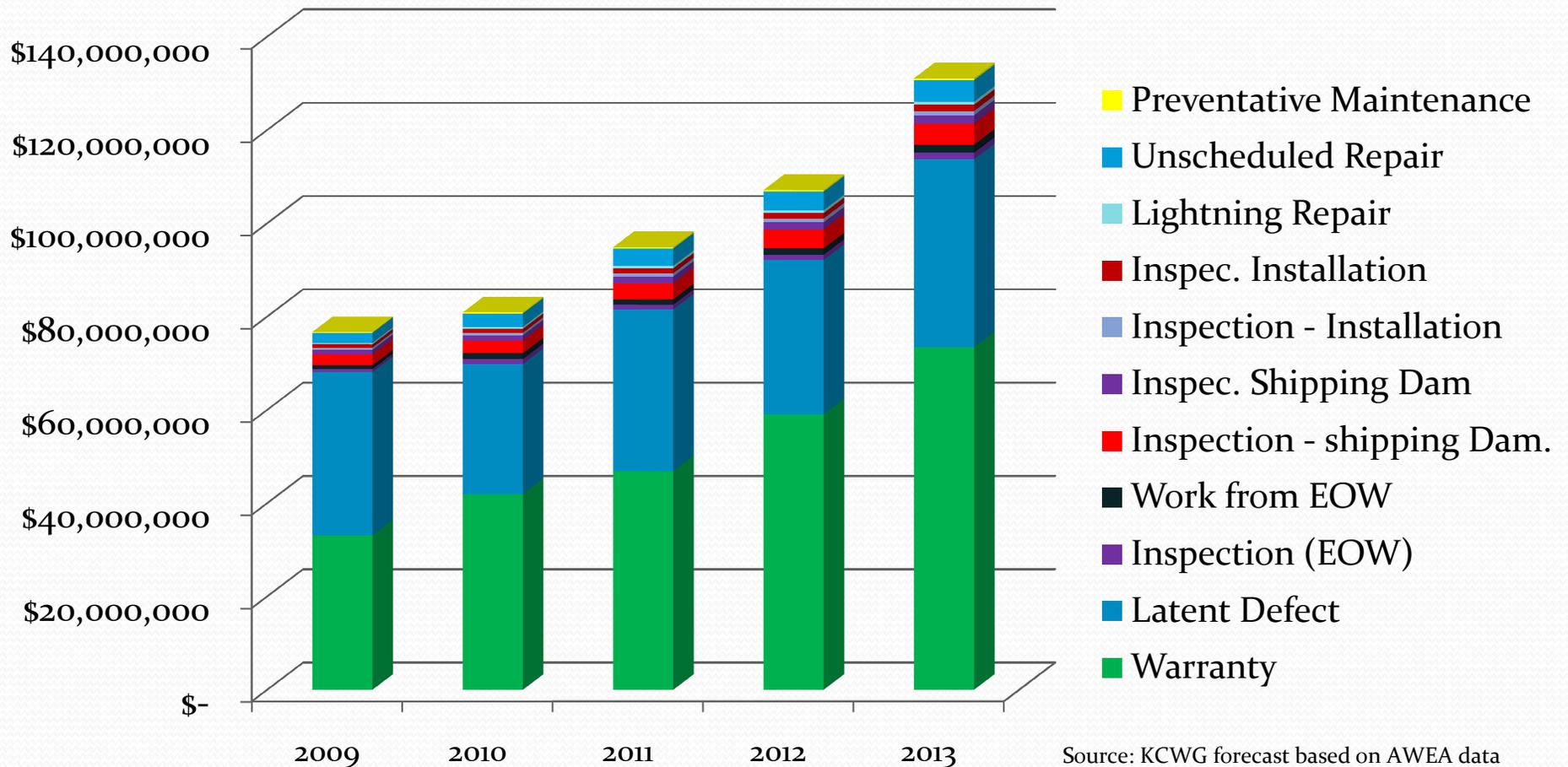


Source: DOE "20% Wind Energy by 2030" report

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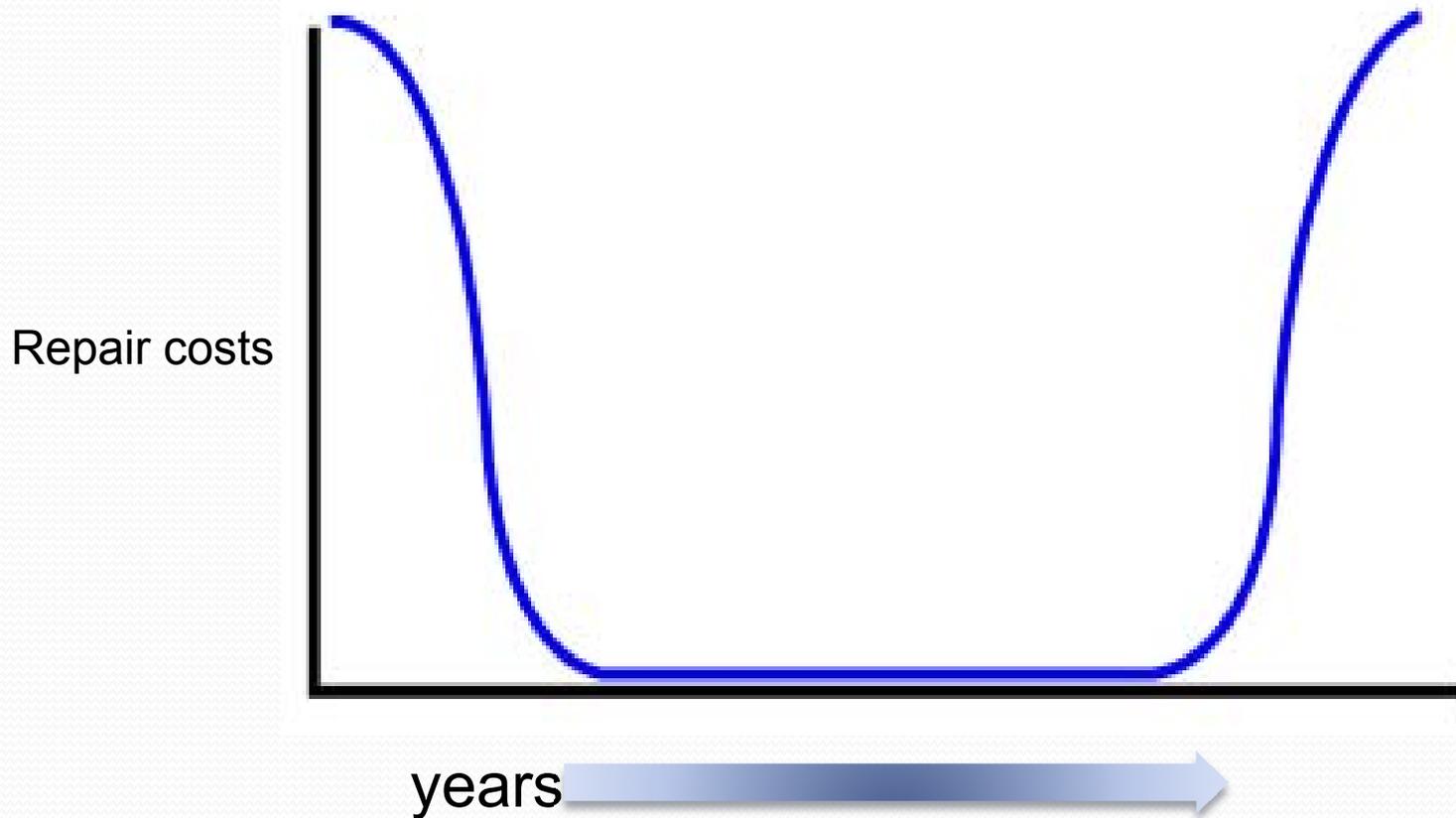
Total Field Service Rotor Blade Market



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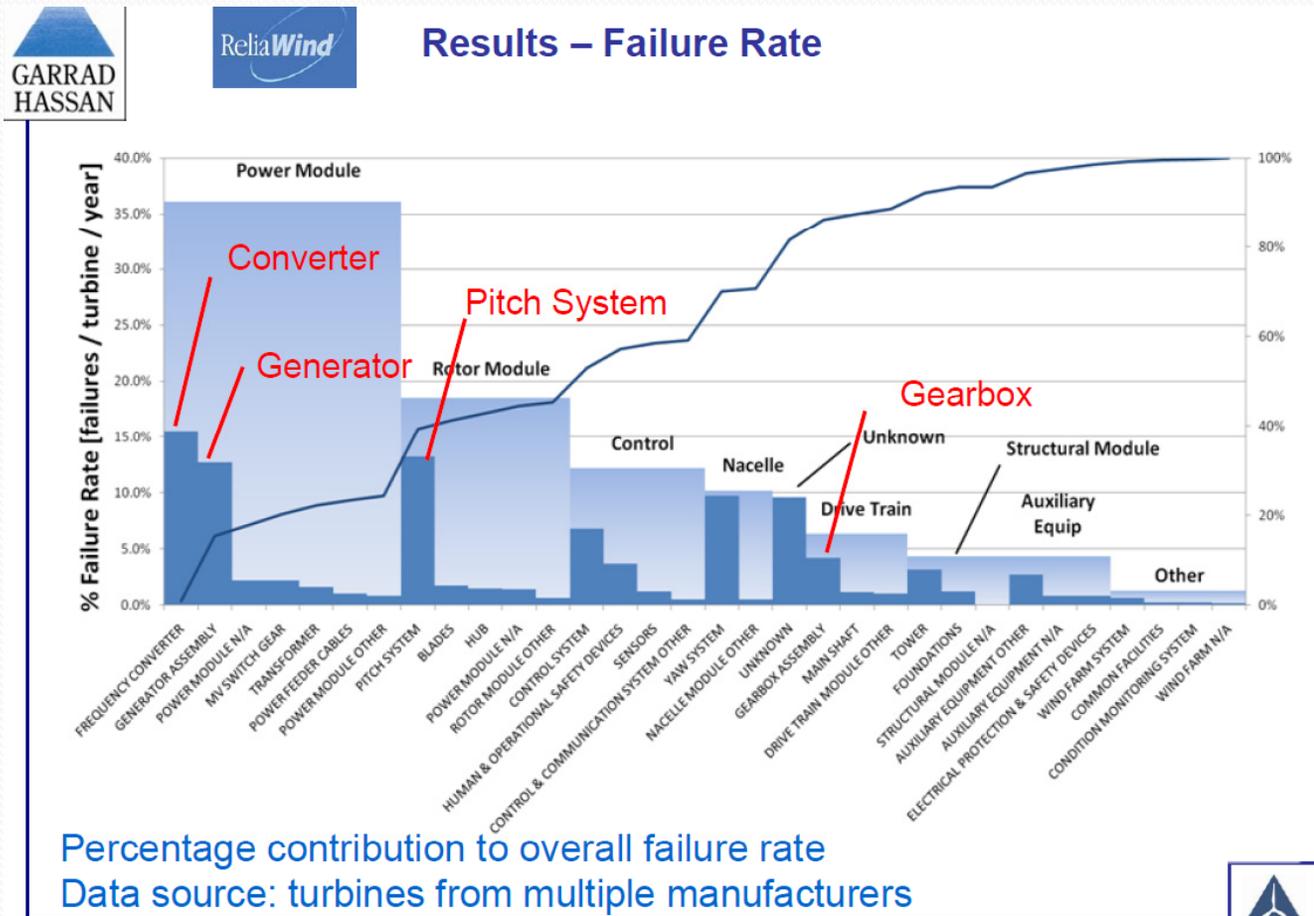
Blade Repair Bell Curve



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Wind Turbine Failure Rate



Source: Garrad Hassan

Practical toolbox for O&M 14

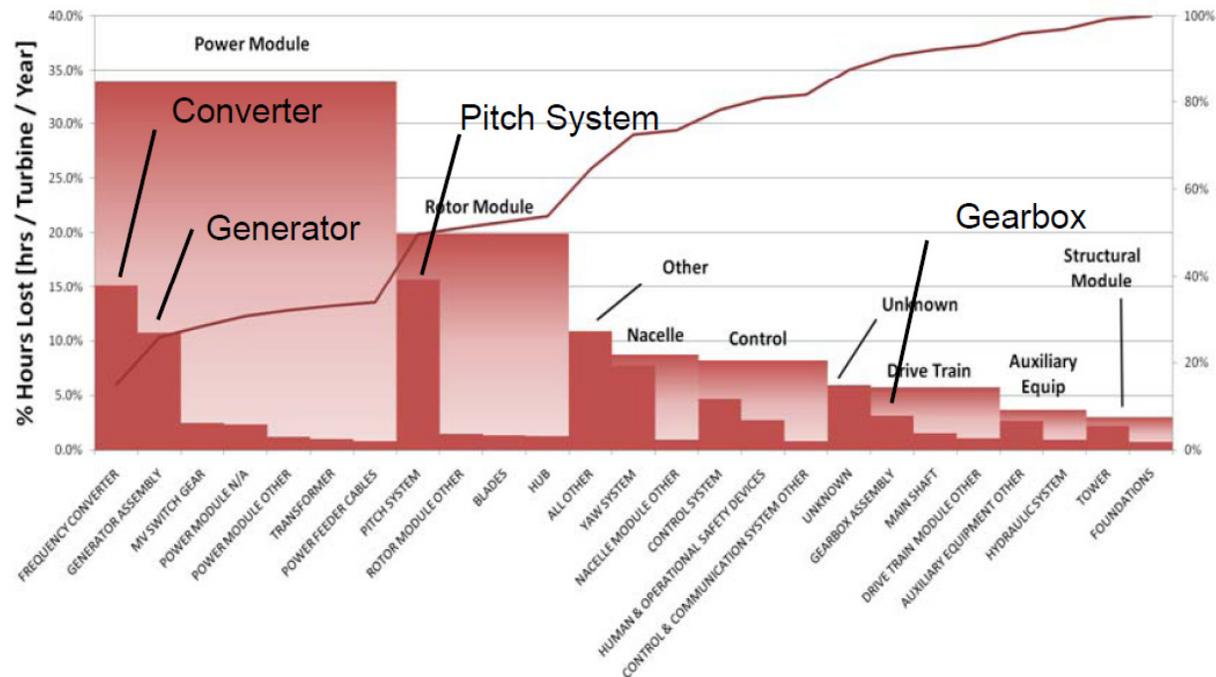
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Wind Turbine Downtime



Results – Downtime



Percentage contribution to overall failure rate
Data source: turbines from multiple manufacturers

Source: Garrad Hassan



Practical toolbox for O&M 15

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Most Important Maintenance Action:

Observe blades!

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Most Important Maintenance Actions:

- Stop, look & listen.
- Binoculars.
- Inspections from suspended platform/crane basket.
- Camera with telephoto lens.

Most problems will be evident from the exterior!



Photo from Pickup Truck (400mm lens)



Source: Knight & Carver

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Getting to the Problem...



Source: Knight & Carver



Source: Knight & Carver

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A Different Suspended Platform..



Source: Knight & Carver

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Another way to go up Tower



Source: Knight & Carver

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Safety First-Tailgate Meeting



Source: Knight & Carver

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Common Blade Problems

- Transportation & Construction.
- Lightning.
- Leading edge erosion.
- Debonding (At Spar or Trailing & Leading edges).
- Dynamic and Aerodynamic Imbalance.



Transportation Damage

Blades are built far from the sites...



Source: Knight & Carver

Trucking blades.



Source: Knight & Carver

Typical shipping damage.

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Lightning Damage



Source: Knight & Carver

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Leading Edge Erosion



Source: Knight & Carver

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Trailing Edge Debonding



Source: Knight & Carver

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Insufficient Bonding Paste.....



Source: Knight & Carver

....Or Bond Line too Thick.

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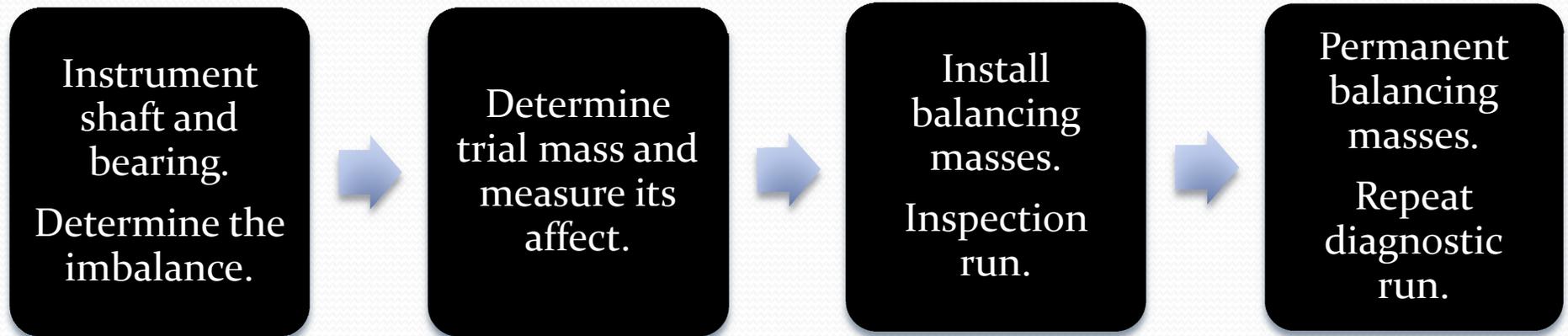


Rotor Imbalance

- Mass Imbalance
 - Moment varies due to uneven blade masses or distribution.
 - Hub imbalance or flange errors.
 - Bent shaft.
 - Blades have absorbed oil or water.
 - Icing.



Dynamic Balancing Process



Aerodynamic Imbalance

- Blades are producing varying power.
 - Uneven blade profiles
 - Built wrong
 - Repairs
 - Erosion.
 - Pitch angle varies from blade to blade.
 - Coning angle errors.



Pitch Angle Measurement



Source: Knight & Carver

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For Existing Wind Turbines ...A Service Plan!

Objectives:

- Increase productivity.
- Increase availability.
- Minimize downtime.
- Reduce/eliminate large repairs and replacements.





KCWG Technology

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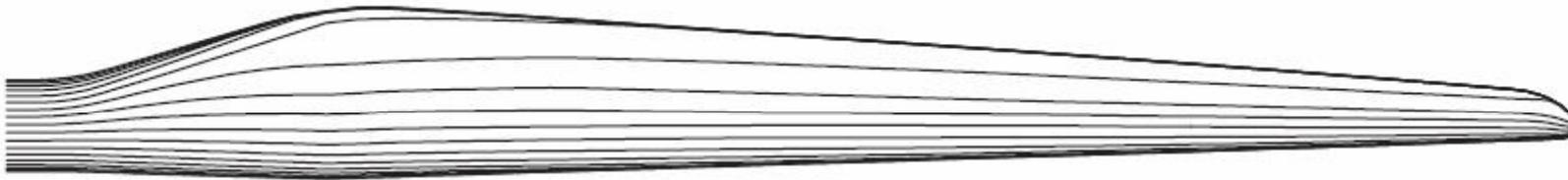


STAR[®] Technology

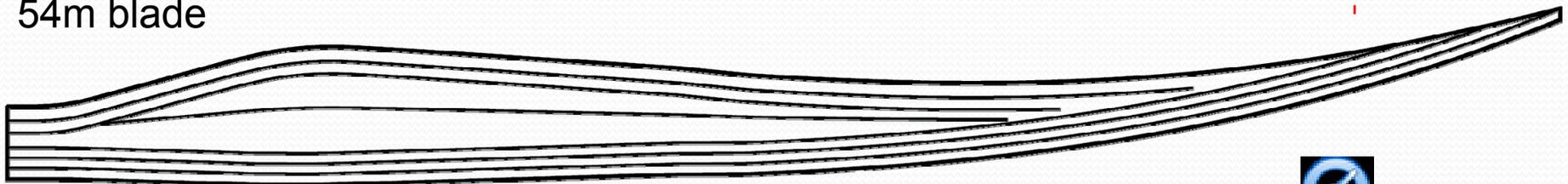
- Planform sweep induces twist.
- Blade twist sheds loads.
- Load reduction allows for a larger rotor which captures more energy.
- Load reduction allows for lighter components.
- Static, fatigue and field tests confirmed model predictions.
- Field tests confirmed 12% + energy capture gain with loads comparable to baseline.

Standard Blade VS. STAR[®] Design

48m blade



54m blade



STAR of the Show.mov

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Source: Knight & Carver

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Source: Knight & Carver

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Appendix

- Inspection Techniques.
- STAR[®] Technology.
- Press Kit.



Thermographic Camera

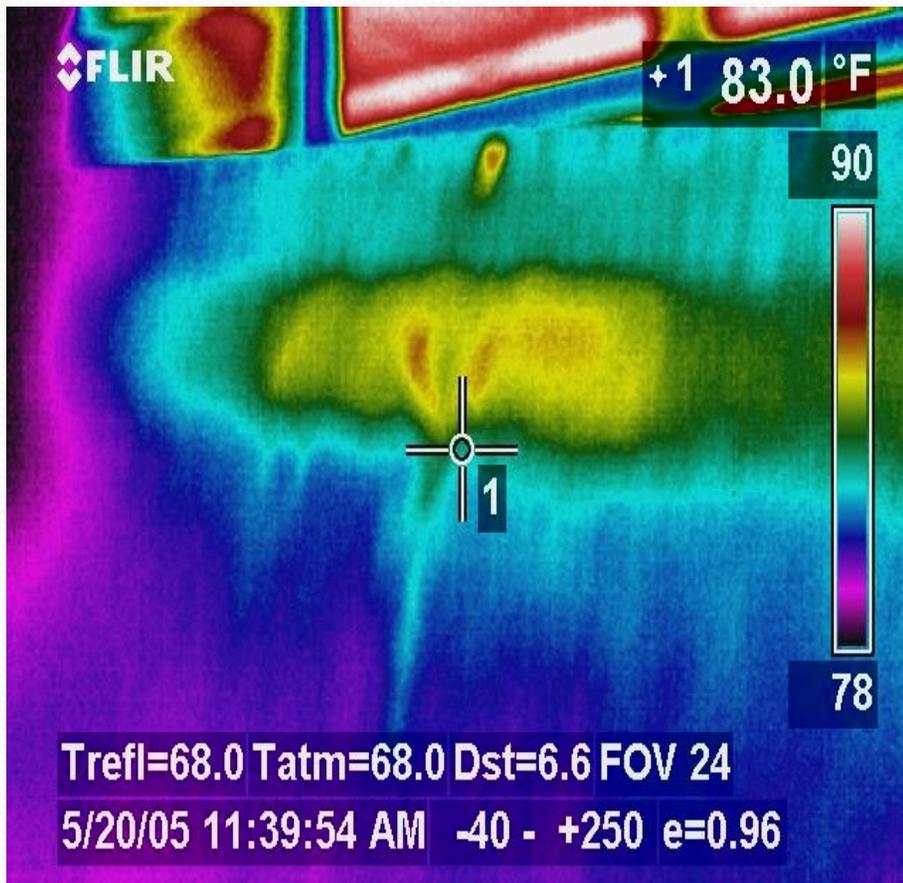


Source: Knight & Carver

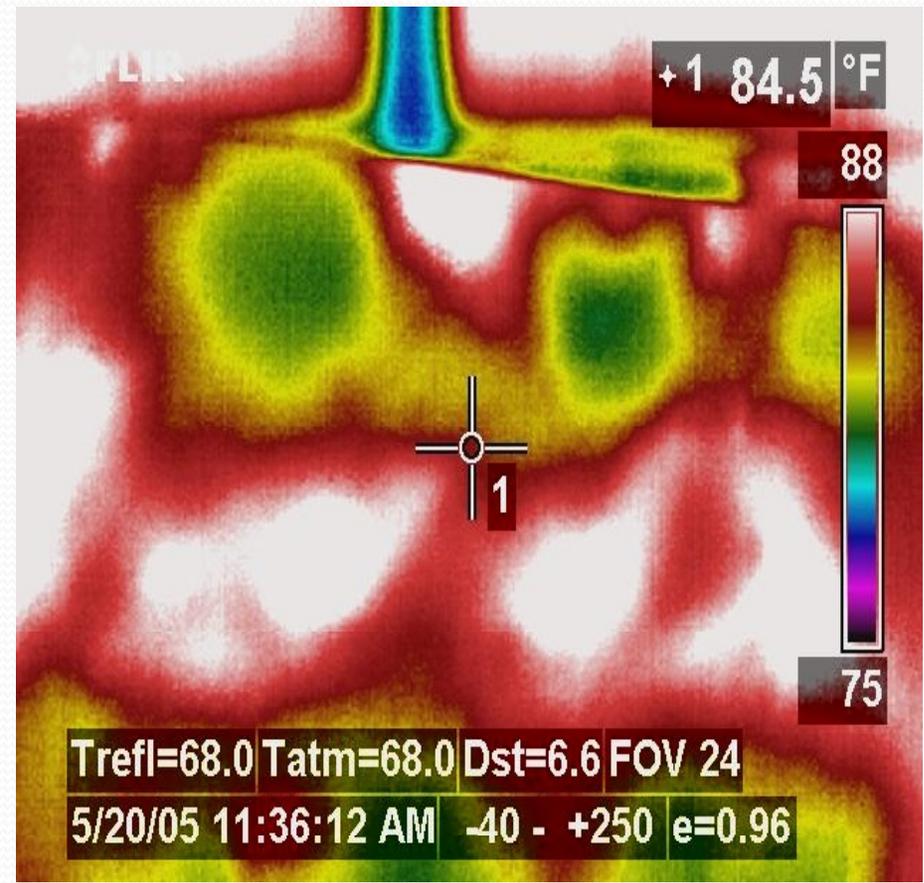
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Thermographic Images



Source: Knight & Carver

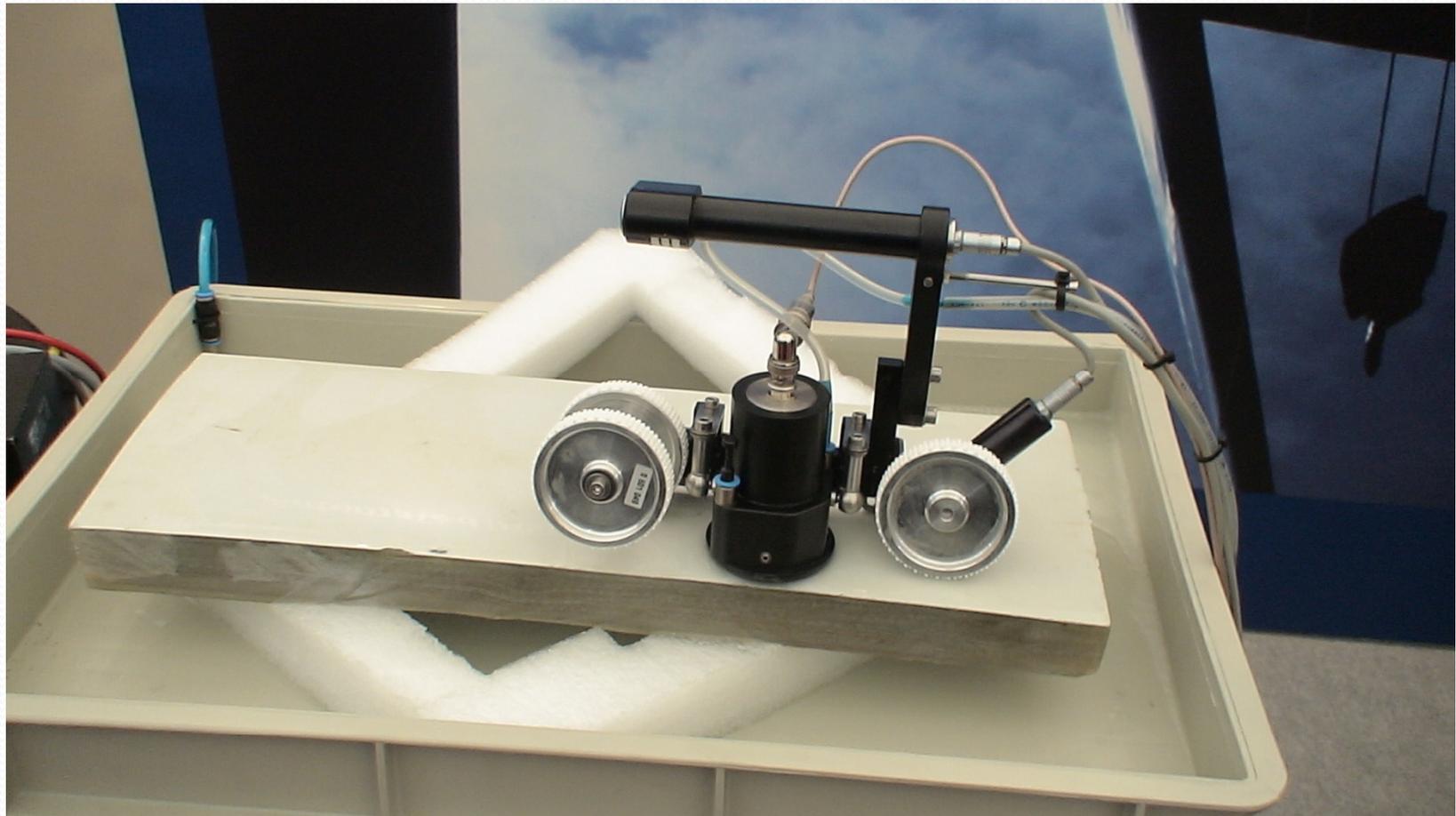


Source: Knight & Carver

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Ultrasound Transducer

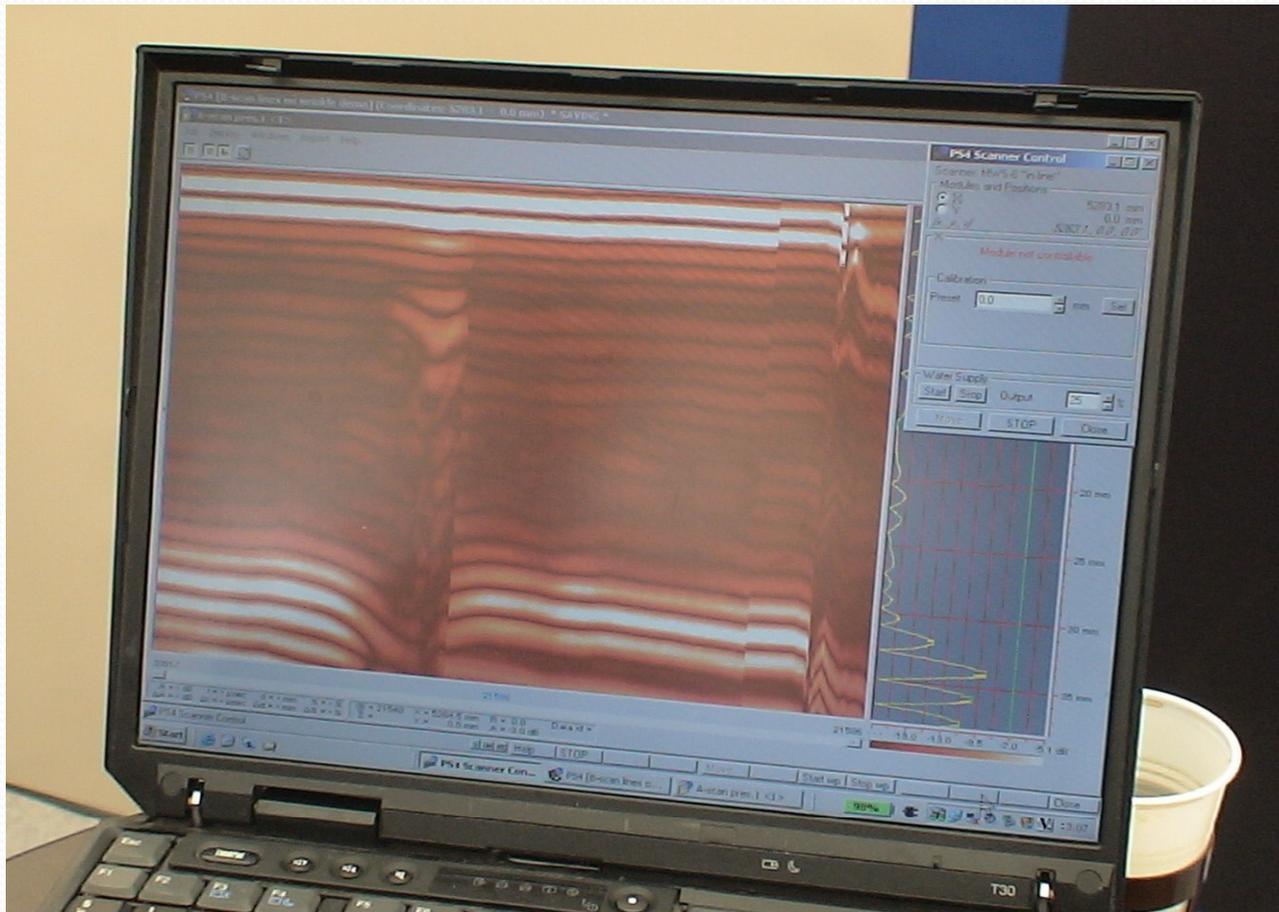


Source: Knight & Carver

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Ultrasound Inspection Image



Source: Knight & Carver

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Infrared Imaging of Blade Interior



Source: Knight & Carver

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Lightning System Testing



Source: Knight & Carver

Digital Low Resistance Ohmmeter



Source: Knight & Carver

Test each receptor

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Lightning Strike!



Source: Knight & Carver

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Sweep Twist Adaptive Rotor[®] Technology

- KCWG realized that a wind turbine can collect more energy and be more productive if the rotor size can be increased.
- If a rotor size is increased, the loads are increased which limits rotor size.
- The STAR[®] technology allows the use of a larger rotor without increasing the loads.
- This was validated when KCWG's 54m STAR[®] rotor replaced a 48m rotor without increasing loads while increasing energy capture by 19% over 18 months.



STAR Blade[®] Workings

- The design reduces loads at the root of the blade by twisting.
- The shape (planform) of the blade causes the blade to twist.
- When the blade twists, the blade tip has a different angle of attack than the rest of the blade.
- The effective area of the blade that produces the power has been reduced.
- The value is that either the blade can now be longer without increased loads on the turbine or the blades remain the same length and other components of the machine can be built less robust (less costly).
- A combination approach could be that the blades are slightly longer with increased reliability for the machine which now is absorbing less loads.



blade.exe

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LWST (Low Wind Speed Turbine Project)

- KCWG competed for a DOE RFP in 2004 to provide solutions for turbines in low wind speed regimes.
- Administered through Sandia National Laboratories, Alb, NM.
- Total project cost \$2.8m with .8m in KCWG cost share.
- Engineering design studies showed reduced loading due to sweep twist.
- Material selection and tooling fabrication were completed in 2006.
- KCWG named this “Sweep Twist Adaptive Rotor”[®] blade STAR[®].
- Prototype manufacturing showed STAR[®] can be produced utilizing current manufacturing techniques.
- **Laboratory and field testing confirmed model predictions.**



Test Results

- The static test at KCWG validated model predictions for deflection, twist, frequency, and stress.
- The STAR Blade[®] fatigue test at NREL verified a design life of 20 years under IEC design loads.
- The field test was conducted in a commercial wind site and STAR[®] increased production by 10-12% over a two month test period.
- The STAR Blade[®] had a design load envelope that was equivalent to the baseline blades.



STAR[®] Value on 2.5 MW Turbine

- NPV 1% increase in energy production =\$30,000.
- STAR[®] blades could increase production by 10%.
- NPV increase of \$300,000.
- Standard blade price \$340,000/set.
- STAR[®] blade price +10% or \$374,000/set.
- NPV of \$300,000 realized by \$34,000 increase cost (12%).
- \$34,000 blade cost increase is less than 1% of the total turbine cost.



Production Increase Potential

- 2010 nearly 10,000mw Wind power installed.
- Annual production of 10,000mw at 35% capacity = 30,600,000 mw hours.
- At \$50mwh production value is \$1,500,000,000.
- STAR[®] blades would enable the same turbines to produce \$150m more annually.
- Additional blade cost returned in additional energy produced in one year.
- Over a 20 year life the blades pay for themselves 20 times.



KCWG Patent Applications

- KCWG has applied for 5 patents.
- Ideas for patents derived through design and fabrication of the STAR[®] blades.
- The patents provide solutions to difficult design & manufacturing issues.
- All patents applicable to swept blades, and one has universal applications to all wind blades.

A Low Wind Blows Fair as Knight & Carver Shipyard Sails Into Wind Turbine Business

July 22, 2009

By Bruce V. Bigelow

The Knight & Carver Yacht Center was founded in 1971 along the southeastern shore of San Diego Bay, where it continues to build and repair large boats, specializing in custom-built yachts and commercial passenger vessels. Because so many boat hulls are made of fiberglass, the National City, CA-based boatyard also has worked extensively with fiberglass composites.

So it was smart, really, when a wind turbine operator called the shipyard roughly 12 years ago to ask if Knight & Carver could repair a broken turbine blade. Figuratively speaking, the yard boss said, "Sure, we'll give it a whirl."

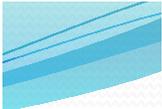
Today the Knight & Carver Wind Group operates as a separate company—a spinout, so to speak—with

"We're seeing a minimum of 8 percent improvement over exactly the same turbines in exactly ... the same place," Brown says. "So we think we have a really good design that we're ready to commercialize."

250 employees, about twice as many as the yacht center. The wind group develops prototype turbine blades at facilities near its headquarters in National City, manufactures 82-foot-long turbine blades in a new facility the company built in Southeastern, South Dakota, and dispatches dozens of wind turbine

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Why We Support the Clean Energy Bill: Jobs, Jobs, Jobs

By Sampson A. Brown, President/CEO
Knight & Carver Wind Group

We're pleased to join Sen. Tim Johnson in his recent support of the Clean Energy Bill. Thankfully, he realizes this is a time for decisive action, not for maintaining the status quo. South Dakotans will surely benefit from his foresight and leadership in Washington on this issue.

As the President/CEO of Knight & Carver Wind Group, with a full-scale, state-of-the-art blade manufacturing and service facility in Howard, we could easily double, even triple our employment to keep up with the increased demand that would result from transitioning to a clean energy economy.

Federal clean energy and climate legislation would put the United States on track to be a leader in clean energy technology, allowing us to catch up to the growing interest in clean energy technology by other economic competitors.

We need Washington to provide the framework that will move our nation forward to a cleaner, more energy efficient future, and comprehensive clean energy and climate legislation could provide that roadmap.

We want Knight & Carver, our 60 employees, the people of South Dakota and America to prosper from a robust new frontier in our nation's economy as the United States reaches for the skies to harness the wind and generate clean electricity and prosperity for generations of Americans.

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Energy bill would create 5,000 jobs

By The Associated Press

September 28, 2009

HURON (AP) -- Transitioning to a clean energy economy with passage of an energy bill pending in the Senate would create 5,000 South Dakota jobs, break the nation's dependence on oil and help solve the climate crisis, the state director of Repower South Dakota said Wednesday.

Wind turbine blade manufacturer Knight & Carver in Howard stands to double or triple its current 60-employee base should the measure pass.

Students are being turned away from energy-related courses offered by technical institutes in Watertown and Mitchell because they fill up so quickly. Graduates not only can remain in the state, but earn excellent salaries.

Matt McGovern of Repower South Dakota led a news conference in conjunction with a national effort to educate the public about the climate change legislation. A final nationwide Made in America jobs tour was Wednesday in Pittsburgh.

Augustana College economist Reynold Nesiba cited findings from a University of Massachusetts study indicating South Dakota could gain up to 5,000 clean energy jobs.

"These are the kind of jobs that would not be easily exportable," he said.

"This is the sort of thing that would boost our economic growth. South Dakota would be one of the big winners in this legislation," Nesiba said.

Not everyone agrees.

South Dakota Farm Bureau Administrative Director Mike Held of Huron said the legislation will have devastating effects on family farms and agricultural production because of rising input costs.

Offsets may help some farmers with energy-related costs, but it will depend on where the producer is located. "Not every farmer lives in a region where wind turbines are an option. Not every farmer can take advantage of no-till. And not every farmer has the land to set aside to plant trees," said Bob Stallman, president of the American Farm Bureau.

The House version passed by a seven-vote margin, with eight Republicans supporting it. But the Senate version will likely be different.

At Dakota fest in Mitchell last month, Sen. John Thune, R-S.D., and Rep. Stephanie Herseth Sandlin, D-S.D., said in its current form the climate change legislation that passed the House would hurt farmers.

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The House bill would require the United States to reduce carbon dioxide and other greenhouse gas emissions by 17 percent from 2005 levels by 2020 and by about 80 percent by mid-century.



Wind Turbine Sector Spinning Faster for National City Firm

September 28, 2009

By MIKE ALLEN, San Diego Business Journal

"Green shoots" are clearly evident at National City's Knight & Carver Wind Group, where employment has jumped to 250 workers today from 30 in 2006, with 150 more on the payroll by the end of next year.

The business, which began as a sideline refurbishing damaged blades for wind turbines generating electric power, now surpasses the luxury yacht building business, which employs 125.

"I think we made some good choices," said Sam Brown, the chief executive who oversaw the shift six years ago from luxury yacht manufacturing and repair.

From the late 1990s until 2002, Knight & Carver's business refurbishing the fiberglass blades was sporadic. But as the number of turbines proliferated and more blades began failing, the business increased.

The company did a thorough study of its operations and found some activities were yielding profits while others weren't.

Blade repair was clearly doing better than yacht repair, Brown said.

"We started trying to get more of that business," said Brown, who joined the company in 2001. "It was good, profitable work and fit within our core competencies."

In 2003, Knight & Carver obtained a breakthrough contract from a large, unnamed multinational corporation that propelled the business to the next level.

"It was a big deal for us," said Brown, who gave the contract amount as "multimillion" dollars.

The contract called for Knight & Carver to build 9-meter blades, which required the business to learn more about production and scale up.

Yacht Repair Sideline

By 2007, what was once a sideline to yacht repairs grew so large that Brown launched a separate division.

Recently, the wind group took another step, working with the U.S. Department of Energy to develop a more efficient blade.

Under the \$3 million project, a new curved design allows the blade to generate more power without





Obama pushes for 'green' jobs

Airdate: March 9, 2008

Reporter: William La Jeunesse, FOX News

Video:

http://www.fox11online.com/dpp/news/nat_fox_ca_green_jobs_200903110851_rev1

NATIONAL CITY, Calif. -- With the U.S. bleeding jobs, President Barack Obama is attempting to breathe life back into the American workforce through spending on green power.

"I will invest \$15 billion a year in renewable sources of energy to create 5 million new jobs over the next decade," Obama said. "Jobs that pay well and can't be outsourced"

"The truth is, the manufacturing jobs can be outsourced and they have been outsourced," said Scott Paul of the Alliance for American Manufacturing.

While installation and maintenance of green power facilities and transmission lines are, by nature, impossible to outsource, the reality is that wind power components are mostly made in Europe while photovoltaic panels for the solar industry are built in the Philippines, Malaysia and China.

"A lot of these technologies were developed in the United States," Paul said. "They're being deployed in the United States, but they're being made elsewhere."

U.S. manufacturers tried to insert a "buy American" clause into the stimulus bill to keep more green energy jobs here, but failed.

One U.S. company that has jumped into renewable energy is Knight & Carver of San Diego. Once a boat builder, the company began fabricating wind turbine blades 18 months ago. Since then, its workforce has grown from 50 to 250 employees.

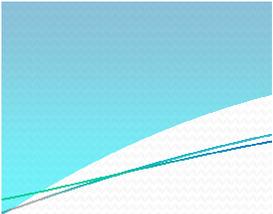
"There's no doubt in my mind that we will see more green jobs here, more manufacturing jobs here," said Sam Brown of Knight & Carver. "All of the business fundamentals mitigate in favor of that happening."

But meeting the president's goal of 5 million new jobs will be difficult with 70-80 percent of all wind and solar jobs in the manufacturing phase, not installation or operation.

Without a change in policy to get American manufacturers into the mix, billions of American tax dollars will be going offshore, stimulating foreign economies instead of our

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News Release

For Immediate Release: June 30, 2009

KNIGHT & CARVER ENDORSES CLEAN ENERGY ACT **‘FIRST BIG STEP TOWARD ENDING AMERICA’S LONG DEPENDENCE ON FOREIGN OIL’**

NATIONAL CITY, CALIFORNIA – Knight & Carver Wind Group salutes the U.S. House of Representatives for last week’s passage of the American Clean Energy and Security Act of 2009.

Commonly known as the Clean Energy Act (H.R. 2454), the legislation promises to bring significant progress to the nation’s energy needs, led by an increased commitment to the renewable energy sources of wind and solar. The bill was passed June 26, on a vote of 219 to 212.

“We believe this bill represents the first big step toward ending America’s long dependence on foreign oil,” said Knight & Carver president/CEO Sampson A. Brown. “While not perfect in its current form, the Clean Energy Act provides a guiding light toward the goal of reducing the nation’s carbon output. It also addresses concerns of global climate change and, most importantly, provides reachable goals for increasing renewable energy production for the future.”

Working closely with the American Wind Energy Association, the wind industry’s leading trade group, Knight & Carver will continue to seek refinements and improvement to the bill as it moves to the Senate for final consideration.

“Our industry needs the definitive road map to a cleaner, more energy-efficient future that this bill provides,” added Brown. “We intend to take an industry leadership role in that process.”

About Knight & Carver Wind Group:

Safety – *Professionalism* – *Experience* – *Craftsmanship* – *Value* – *Integrity*
Knight & Carver provides wind blade repair, maintenance and fabrication services to customers throughout the U.S., Europe, Latin America and Canada. Knight & Carver operates full-service blade fabrication and





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